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Terahertz and micro four point probe conductivity mapping of large area CVD grown graphene films

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Summary

We demonstrate mapping of magnitude and variation of the electrical conductance of large area CVD graphene films by terahertz time-domain spectroscopy (THz-TDS) and micro four-point-probe (M4PP). Non-trivial correlations between results obtained with the two techniques are discussed in relation to electrical properties of the graphene films.

Introduction

Graphene electronics is receiving immense amounts of attention motivated in part by the potential use in e.g. transparent electrodes, integrated circuits, RF electronics, spintronics, etc. While commercial interest in graphene has yielded impressive techniques to produce large-area graphene [1], no technique capable of mapping electrical properties of large area graphene films has yet been developed. As a result, the electrical characterization taking place today comprises 'off-line' transport measurements in lithographically defined structures and cumbersome STM or conductance AFM measurements, none of which are suitable for revealing the large-scale uniformity of electrical properties in the films. This leaves a gap in the electrical characterization techniques for graphene that could perhaps be filled by THz-TDS conductance mapping, as it has already been shown that single layer CVD-grown graphene can be imaged using THz-TDS [2].

Results and discussion

Here, we present quantitative mapping of the electrical conductance of large area CVD grown graphene on a cm scale by two independent measurement techniques; non-contact THz-TDS mapping and contact-based M4PP mapping.

The sheet conductance maps shown in figure 1(a) and (b), obtained by THz-TDS and M4PP, identify the same overall conductance features with a slight blurring due to the larger spot size used to record the THz image. It is evident from comparison of the conductance maps with the microRaman image in figure 1(c) and the optical microscope image in figure 1(d), that sheet conductance mapping reveals significant additional information about both magnitude and spatial variation in the electronic properties, although we do observe some common features.

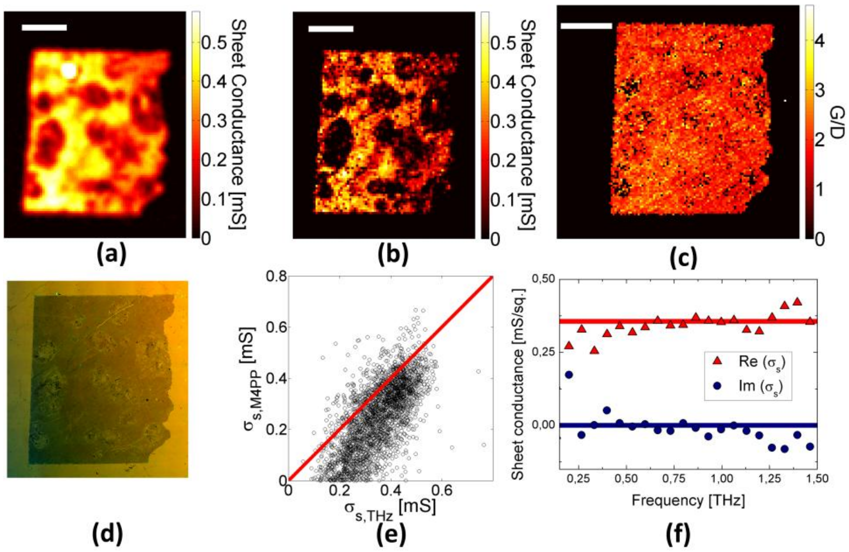

Fig 1. CVD graphene film on 90 nm SiO_2 on Si. (a) THz sheet conductance image, (b) M4PP sheet conductance image, (c) microRaman image intensity ratio G/D, (d) tiled optical microscope image, (e) comparison of THz and M4PP sheet conductance pixel-by-pixel, and (f) complex, frequency resolved sheet conductance recorded in a homogeneous area in the center of the film. Scale bars in (a), (b), and (c) are 2 mm.

Figure 1(e) shows a plot correlating the measured sheet conductances $\sigma_{s.THz}$ and $\sigma_{s.M4PP}$ pixel by pixel, from which we observe that the M4PP conductance is generally lower than the THz conductance through a non-trivial correlation. As we find a flat drude-like response in the entire measurable range 0.2-1.5 THz as shown in figure 1(f), we believe that the discrepancy is caused by an uneven distribution of rips and damages caused by post-growth transfer of the graphene, which can significantly lower the M4PP DC conductance, but has a negligible impact on the nanoscale THz conductance.

Conclusion

We show that M4PP and THz-TDS sheet conductance mapping are very capable, useful and potentially extremely fast metrology tools for quantitative characterization of the magnitude and spatial variation of electrical properties of large area CVD graphene films.

The observed correlation where M4PP sheet conductance shows a non-trivial tendency towards lower values than corresponding THz conductance values indicate that THz and M4PP conductance maps together can provide added information about the impact of defects on electrical properties of the graphene film.

References

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